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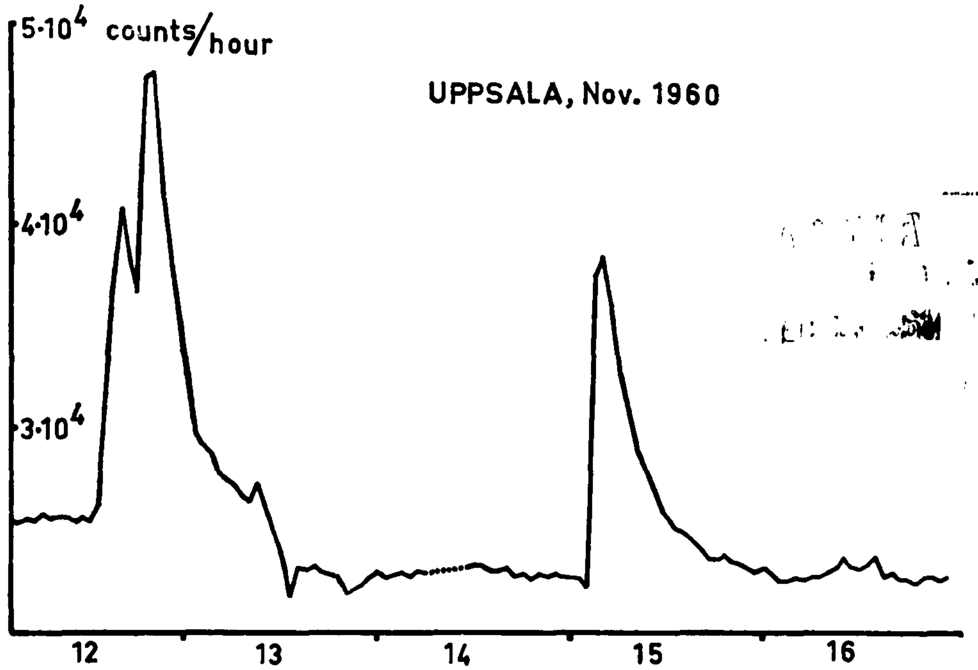

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COSMIC RAY FLUCTUATIONS IN THE NUCLEONIC
AND MESON COMPONENTS IN UPPSALA
DURING NOV. 10 - 22, 1960

by Eric Dyring

Technical Note No. 9
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Abstract

The large cosmic ray fluctuations during the period Nov. 10 to 22, 1960 in the nucleonic and meson component seen by the Uppsala Cosmic Ray Station are presented in 5- or 15-min. values as well as 1-hour values. Correlation is made with sun and geomagnetic data. Some comparisons are made with other stations.

Table of contents

1. Introduction

The extraordinary geophysical events during November, 1960 correlated with strong flare activity on the sun have attracted great interest and an intense research has been started around these phenomena. The series of geophysical activity will give a rare occasion to test different models formed to explain the variations of the geophysical parameters at periods of sun activity and may give new aspects on the problem. The natural line of the work is to use the collected data for a world-wide study of the events.

Until now a number of papers have been published about the November events. They have all been more or less a review of the geophysical activity seen from one or a couple of stations and including some sketches of explanation. This technical note presents the cosmic ray variations connected with the flares in November, 1960 observed by the Uppsala Cosmic Ray Station with the two international standard instruments; the IGY neutron monitor and the duplex cubical counter telescope. Correlations with observations of the sun and the geomagnetic activity are presented.

2. Equipment

The Uppsala station is situated at 59° 55´N, 17° 55´E at sea level and has a cut-off rigidity of 1.17 GV acc. to the formulations of Quenby and Webber (Cogger 1960). The neutron monitor is built after the IGY recommendations with 12 proportional counters (see Sandström, Lindgren 1959) with a mean counting rate of 25 000 counts per hour.

The duplex cubical counter telescope is fitted with a filter, equivalent to 10 cm Pb with a mean counting rate of 100 000 counts per hour. The registrations are made every hour and for short time registrations a centralograph is used, described elsewhere (Sandström, Lindgren 1959).

The atmospheric pressure is recorded photographically every hour by a precision aneroid barometer and a 7-day barograph is used for short time registrations.

3. Corrections for atmospheric effects

All the nucleonic and meson data are in this paper reduced to an atmospheric pressure of 1010 mb by the usual method. The following coefficients have been used:

Neutronmonitor = -0.737 per cent per mb
Counter telescope = -0.15 per cent per mb

No other corrections of atmospheric effects are made.

By comparing two stations, Mt Wellington and Hobart separated by 707 meters in altitude, Parsons (1960) has found a pressure coefficient for the nucleonic component during the November increases of about 1 per cent per mb and stressed the importance of care at correction when reducing the data to a certain pressure level.

At Uppsala the atmospheric pressure was fairly constant during the

periods. During the first event 13 00 UT, Nov. 12 to 15 00 UT, Nov. 13 it varied within 1020 - 1023 mb, during the second event 01 00 UT - 17 00 UT Nov. 15 within 1010 $\pm$ 0.5 mb; thus no corrections are made, and during the third event 20 00 UT the 20th to 04 00 UT the 21st Nov. 1960 1014 - 1017 mb. The constance of the atmospheric pressure will then give a negligible effect on the corrected values by using a wrong pressure coefficient. For the first event some caution is to be made when comparing the result with other stations.

4. Errors

The standard errors of data from the two international standard instruments have been estimated elsewhere (Dyring 1961). The following values were found: for data corrected for atmospheric pressure:

Neutron monitor: $\sigma_N = k_1 \sqrt{N}$ $\quad 1.2 \leq k_1 \leq 1.3$

Counter telescope: $\sigma_N = k_2 \sqrt{N}$ $\quad 1.15 \leq k_2 \leq 1.20$

according to the pressure level during the interval of registration. The low value stands for the mean pressure equal to 1010 mb to which the data are reduced and the upper values for 1030 or 990 mb. At 1010 mb pressure and 100 per cent relative intensity the standard errors are as follows:

Neutron monitor	1-hour value	0.08 per cent
	15-min. "	0.16 " "
	5-min. "	0.37 " "
Counter telescope:	1-hour value	0.04 " "

For estimating errors of different parameters of the events a kind of maximum error has been used. The magnitude is wholly dependent of the time interval of registration.

5. Sun activity during Nov. 10 - 22, 1960

The observations of the sun including all flares of an importance = 2 taken from the National Bureau of standards are tabulated.below. The data are also marked in Fig. 2.

Table 1

Date	Time of flares observed by various observatories UT	Importance. Mean from various observatories	Mc Math Plage Region and Mer. Distance			
			5925	5927	5930	5932
10/11	10 09-14 30	3	29°E			
12/11	13 23-19 22	3+	04°W			
13/11	13 08-13 51	2				60°E
14/11	00 15-01 00	2	14°W			
	02 46-05 20	2+	19°W			
	21 14-21 54	2	24°W			
15/11	02 07-04 27	3+	33°W			
18/11	20 19-20 30	1+		90°W		
19/11	15 22-16 49	2	90°W			
	17 41-18 38	1+				32°W
20/11	17 45-18 00	2				50°W
	~ 20 15?	3?	~ 120°W?			
	21 14-22 55	1+			90°W	

6. Registration of the nucleonic component at Uppsala during Nov. 10 - 22, 1960

All values are expressed in per cent of the mean intensity during the 12 proceeding hours of the event and are corrected to atmospheric pressure. In Fig.1 which is a survey of the whole period Nov. 10-22, 1960, the mean intensity is calculated from the period 00 - 13 UT Nov.12, 1960. This survey shows the cosmic ray variations from the neutron monitor and the duplex cubical counter telescope in 1-hour values together with geomagnetic and sun data.

The increase Nov. 12, 1960: The increase is strongly correlated with the 3^+-flare in the Mc Math Plage region 5925 at 13 23 UT the 12th Nov. The whole event is most interesting due to the unusual shape of the increase. A first slow rise to a maximum is followed by a decrease before a sharp and well-defined increase gives the last part of the event a shape similar to the big cosmic ray increase Feb.23, 1956. This certainly gives an unusual opportunity of testing models of explanation. Steljes et al. has pointed out that the first slow increase can be described by a model suggested by Mc Cracken and Palmeira (1959). The slow increase is due to diffusion of solar protons through the lines of force in a magnetic bottle formed by the 3-flare in Mc Math region 5925 at 10 09 UT Nov. 10, 1960. The second phase of this event is the rapid increase at 19 00 UT. The increase can be explained by

1. A new flare
2. A depression of the cut-off rigidity
3. An increase of the cosmic ray flux around the earth
4. A composition of 2 and 3

No observations give any indications that there has been a new flare which can be correlated with this increase. de Feiter et al. (1961) suggest that the increase is due to a cut-off of the rigidity connected with an intense geomagnetic storm starting around 19 UT while Steljes et al. (1961) consider it caused by a change of the cosmic ray flux in space. It will hold for high latitude stations but suggest that for stations at lower latitudes it can be a composition of 2 and 3.

By comparing the observations from Uppsala, Nederhorst den Berg, Limeil and Pic du Midi de Feiter et al. (1961) found that the rigidity spectrum shows a different appearance between the first and second part of the Nov. 12 increase. This is confirmed by studying the observations from a world-wide net of stations.

Fig.2 shows the registration of the neutron monitor at Uppsala for the Nov. 12 event in 5-min. values. From this we find the following characteristics:

	First part	Second part
Onset time UT	14 45 $\pm$ 5	19 00 $\pm$ 3
Time of max. UT	16 10 $\pm$ 5	20 30 $\pm$ 10
Max.(%) above pre-level	64	97

The increase Nov.15, 1960. This increase is obviously connected with the 3^+-flare at 02 07 UT in the same Mc Math plage region 5925 as the two preceeding big flares. The shape consists of a steep rise and is followed by a three hour long constant level of the intensity. The model suggested by Steljes et al. (1961) is that the earth is situated in the "magnetic bottle" and the solar particles easily travel along the line of force to the earth, thus giving a sharp increase. In the previously mentioned study de Feiter points out that the rigidity spectrum of this increase is similar to that of the first part of the Nov. 12 event. This is also confirmed by comparing observations from stations around the world.

Some interesting features may be mentioned. Some stations mostly situated on the American continent as Mt. Washington, Sulphur Mt., Ottawa, Deep River, Chicago but even Mawson have a steep continuous rise to a marked maximum around 03 UT while other stations as Uppsala, Bergen, Leeds, Ellsworth, Mt. Wellington, etc. show a rise in two steps separated by a slower rise around 03 UT at the time when the above mentioned stations have their marked maximum. Fig.3 shows the

registration of the neutron monitor at Uppsala in 5-min.values. We find:

Onset time UT	02 37 ± 2
Time of max.UT	03 08 ± 7
Max.(%) above pre-level	78

The increase Nov.20, 1960. Carmichael et al. (1961) have reported a small cosmic ray increase starting 20 55 ± 10 UT Nov. 20, 1960 at the registration of the neutron monitors at Sulphur Mt. and Deep River. No visible flare which can be correlated with this increase is observed. The authors then suggest that the increase is due to a large flare on the far side of the sun. The most likely place ought to be the Mc Math plage region 5925 which has already produced the three large flares at Nov. 10, 12, and 15, 1960. The time of the flare will then be approximately 20 15 UT. The beam connected with this flare has to be strongly bent.

The observations of the neutron monitor at Uppsala is shown in Fig. 4 in 15-min. values.
The following data are found:

Onset time UT	21 00 ± 15
Time of max.UT	23 30 ± 15
Max.(%)above pre-level	6 - 7

7. Geomagnetic activity and registration of the meson component at Uppsala during Nov. 10 - 22, 1960.

MIT has reported an increase of the meson component of about 1 per cent above the pre-level starting about 13 30 UT Nov. 12, 1960 connected with the flare at 13 23 UT. The registrations at Uppsala show no signs of increases of the meson intensity during the whole event. However, the statistics of the Uppsala registrations are not comparable with those of the MIT telescope. Fig. 1 shows the meson registration in 1-hour values. A series of Forbush decreases have then been registrated in the meson component which can be associated with sudden commencements. The connection of the sudeen commencement with the large flares on the sun during the event in Nov. 1960 has been discussed by Steljes et al.(1961) and Ortner et al. (1961). Table 2 gives a survey of the large flares, sudden commencements and Forbush decreases. The sudden commencements are taken from the monthly reports from Göttingen.

Table 2

Flares			Sudden commencements		Forbush decreases		
Date	Time of start UT	Importance	Date	Time UT	Date	Time of start UT	Time diff. betw. flare and SC in hours
10/11	10 09	3	12/11	13 48	12/11	19 30±30	52
12/11	13 23	3+	13/11	10 21	13/11	10 30±30	22
15/11	02 07	3+	15/11	13 04	15/11	13 00±30	11
20/11	20 15?	3?	21/11	06 32	21/11	19 30±30	10

In Table 2 we find an interesting feature. The time difference between the start of the flare and the connected sudden commencement is decreasing in the series of beams produced by flares on the sun. This indicates that the plasma beam has a more easy advance in the space when an earlier beam has prepared the way.

The suggested explanations of the cosmic ray fluctuations by Steljes et al. (1961) built on the model by Mc Cracken and Palmeira (1959) will fit the observations from Uppsala fairly well. Certainly a lot of fine structure analysis can be further made on the observations in a world-wide study.

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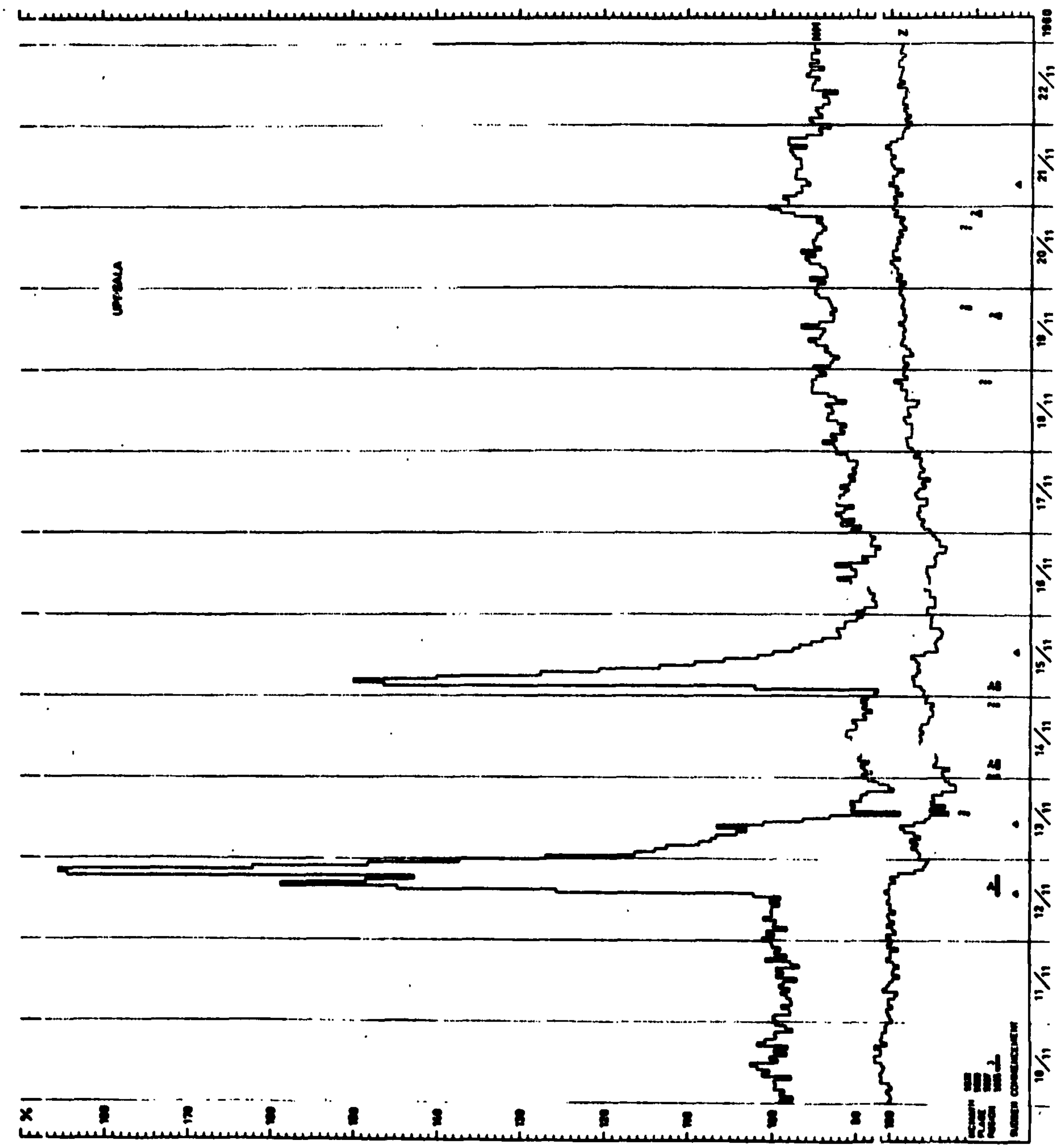

Fig. 1. 1-hour values from the neutronmonitor and the cubical counter telescope at Uppsala. The sudden commencements and the observed flares on the sun are marked under the intensity curves.

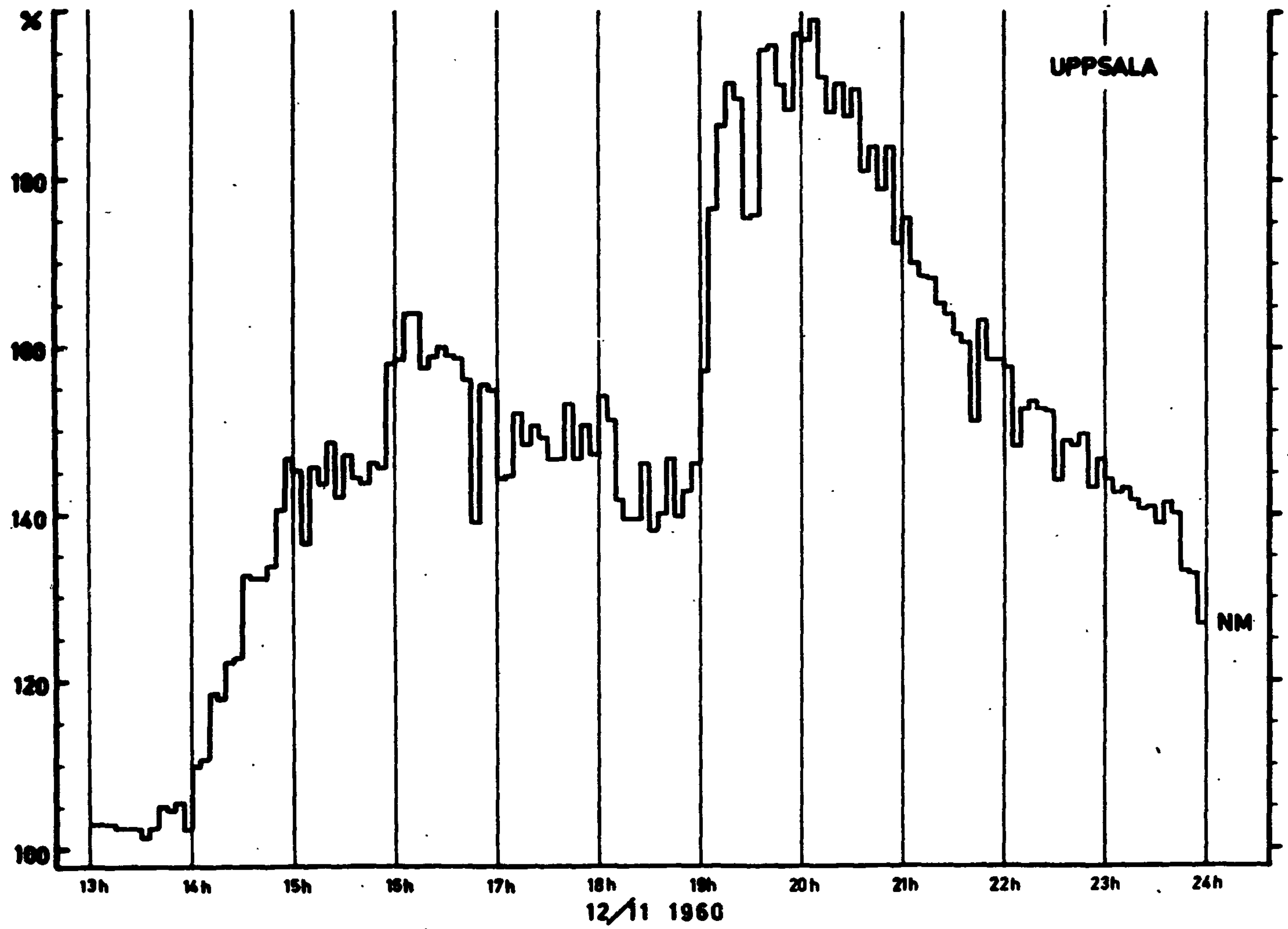

Fig.2. 5-min values from the neutronmonitor at Uppsala for the first cosmic ray increase the 12th Nov.1960.

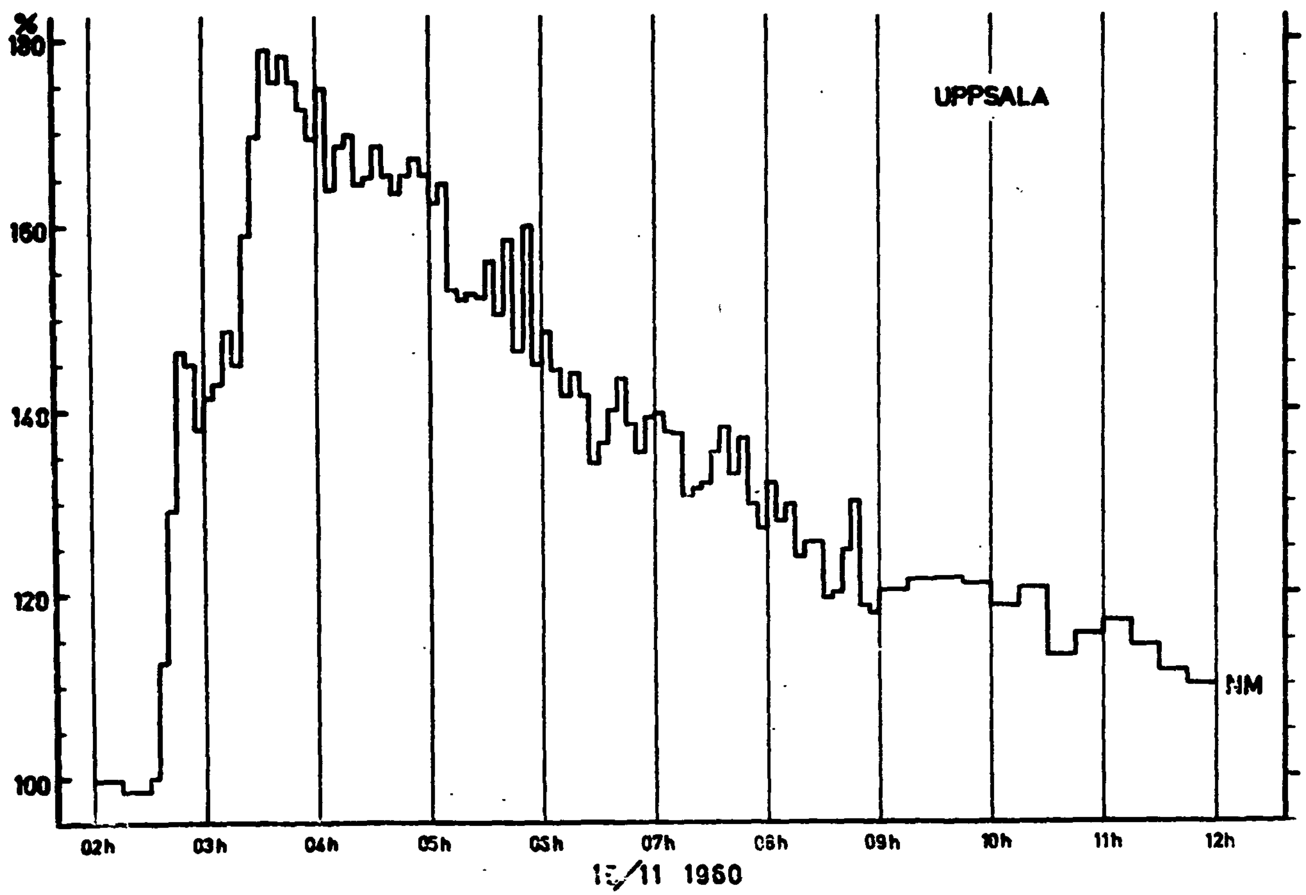

Fig.3. 5-min values from the neutronmonitor at Uppsala for the second cosmic ray increase the 15th Nov. 1960.

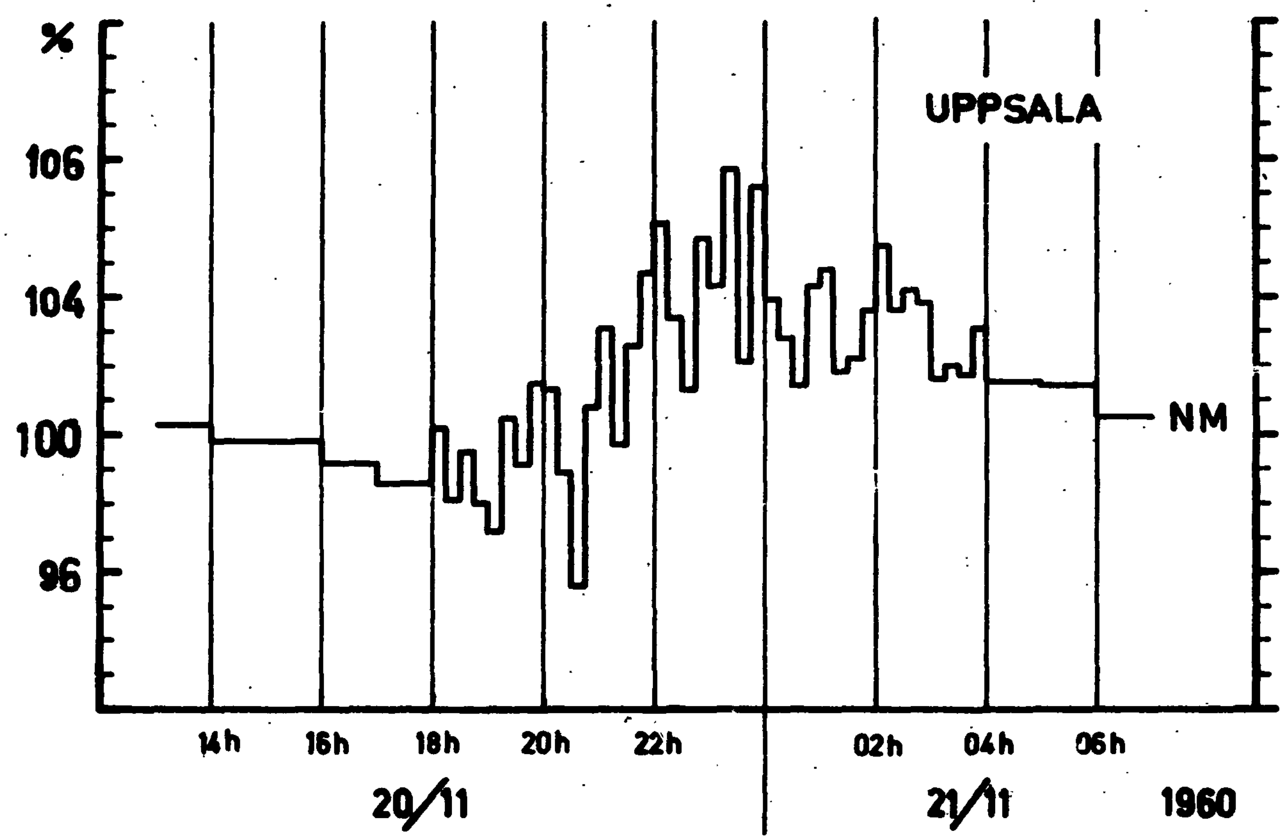

Fig.4. 15-min values from the neutronmonitor at Uppsala for the third cosmic ray increase the 20th Nov.1960.

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